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Community risk perception for flood management: A structural equation modelling approach

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ABSTRACT

The importance of considering risk perception for the support of flood risk management is widely recognised. Therefore, evaluating citizens' risk perception is essential to understand the elements belonging to the social sphere that can affect the increase of risk. This knowledge can support policy makers and disaster managers in establishing more effective management strategies, priority setting, resource allocation and prevention activities. The presence of urban areas exposed to flood risks poses complex decision-making problems for the planning and management of future organisations of local territories and communities.

This work provides an assessment of citizens' perception of flood risk through the construction of a Structural Equation Model (SEM) to identify useful elements to support flood management in a new type of vulnerable areas which have 'episodic streams' called *lame*. This was achieved by investigating the citizens' risk perception and knowledge in the city of Bari. The data was collected using a online survey. Based on the data from 752 respondents, our modelling results provide insights and suggestions to support flood management decision-making as they highlight the heterogeneity of the sample involved, bringing out the categories of citizens most exposed to risk, to which specific measures can be addressed.

1. Introduction

Risk perception assessment to support flood risk management has now become critically important. Evidence shows that risk perception can affect citizens response to a flood event. Citizen response is also capable of amplifying the risk itself [1]. Therefore, assessing citizens' risk perception can lead to the understanding of the elements belonging to the social sphere that can affect the perception of risk, in order to support policymakers and disaster managers in establishing more effective management strategies and plans, priority setting, resource allocation and prevention activities (e.g. Ref. [2]).

The relevance of these elements is highlighted by that the fact that the traditional structural measures for mitigating flood risk could not be sufficient to reducing the exposure and vulnerability of surrounding areas. Exploiting non-structural measures for reducing the incidence of subsequent damages of flood events can be desirable, also implementing integrated actions between urban planning and emergency management, which include the study of community behaviour in order to prevent flood event effects [3,4].

Flood risk management decision-making can be improved by integrating the role of people's perception of risk. A deeper investigation of perception, in its different dimensions and at different levels, provides insight into the social elements that contribute to the definition of flood risk [5–8].

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As a confirmation of this aspect, the International Risk Governance Council stresses the need to integrate risk perception into risk governance as part of the social context [9]. Therefore, risk management is not only a scientific challenge but also involves a social effort [10]. This attention to social dynamics is also encouraged in national policies in Europe, based on the integration between flood risk assessment and mitigation and general societal analysis, as also suggested by the EU Floods Directive 2007/60/EC [11].

The existence of urban areas exposed to flood risks poses complex decision-making problems for the planning and management of future organisations of local territories and communities [12]. Urban plans have often been undermined by flood events, not only in terms of the current and prospective upheaval of economic and environmental resources but also of the social, psychological, and cognitive impacts on communities and their resilient capacities [13].

The literature shows the complexity and ambiguity in the programming and planning of risk management activities. A research streamline emerged a couple of decades ago, particularly addressing the risk of unpredictable, unknown, and unexpected events in programming and planning activities [14–16].

In this context, therefore, understanding the social aspects contributing to the definition of risk to take non-structural actions is as essential as working with structural actions as engineering or architectural works aimed at risk mitigation [17]. It is useful, in accordance with an integrated approach to risk management, to acquire data and information on individuals and communities living in areas exposed to hydrogeological risk and to define models capable of illustrating the complexity of the social and physical systems that describe a phenomenon [18].

Numerous attempts have been made to use models of various origins, (e.g.,stochastic, deterministic, agent-based, cellular automata, neural network models, to address these problems, also resulting in the establishment of important ad-hoc research networks (e.g., DMDU) [19]. The issue of flood risk is well suited to be investigated through hybrid approaches that also include social and qualitative aspects, thus arousing significant importance for spatial planning. Technical and exclusively quantitative approaches, such as those prevalent in risk analysis, are inadequate to reflect the complex pattern of individual risk perception [9].

Structural Equation Models (SEMs) applied to flood management are helpful statistical tools which could provide insight into the factors affecting flood risk perception. Some preliminary studies have already provided significant insights on this subject. For example, Terpstra [20] used an SEM model to predict the flood preparedness intentions of Dutch citizens, including previous experience, confidence in public flood protection, and perceptions of flood risk. Renald et al. [21] exploited SEM to assess the factors that influence the resilience adaptation model of the city of Jakarta, which is subject to constant flooding. Further, Liu et al. [22] used SEM to structure and investigate the direct and indirect factors affecting emergency evacuation capacity for rural households subject to risk of flooding. Ha Anh et al. [23] employed partial least squares structural equation modelling (PLS-SEM) to identify the interrelationships among determinants of household vulnerability to flooding in Cambodia and the Mekong River Delta in Vietnam. Finally, Wang and Zhang [24] used SEMs to structure and measure the interaction between urban flood resilience and subdomain resilience (as economic, political, human, social, institutional, physical and natural resilience). As such, all these studies do not focus on the estimation of how the community perceived the risk of floods.

There are instead a few recent studies using SEM to measure flood risk perception for communities. For instance, Jega et al. [25] used SEMs to examine farmers' risk perceptions, with a focus on the impact of floods on smallholder farmers' livelihoods in Kelantan, Malaysia. Huang et al. [26] adopted the SEMs to explore the quantitative relationship between socio-demographic factors, risk perceptions, and flood protection behaviours. These studies provide new findings on factors can affect flood risk perception. However, they focused either on very specific populations, such as farmers in specific geographical areas.

This work aims to investigate the nature of factors affecting risk perception in a vulnerable area crossed by episodic streams called *lame,* which are characterised by the presence of water only after very intense rainfall events. To achieve this goal, this paper proposes as a case study the city of Bari (south-eastern Italy), whose metropolitan area is characterised by the presence of several *lame*. Bari presents a rather densely urbanised and populated metropolitan area with vibrant socio-economic dynamics, significant but fragile and very sensitive to sudden upheavals like any context in Southern Italy [27,28]. Moreover, the relevant degree of urbanization to which this area has been subjected make the interaction between these episodic streams and the population very intense.

To assess the flood risk perception of Bari, a online survey is proposed. The online survey was used to collect data from 752 participants and was used to estimate a SEM. As such, this work provides an assessment of citizens' flood risk perception through SEM, to identify social elements affecting risk perception, to support flood management.

The paper is subdivided into six sections. After the present introduction, Section 2 section shows the aim and hypothesis. Section 3 presents methodology and the application to the case study of Bari. Section 4 shows the results and is followed by a discussion in Section 5. Conclusions and final remarks close the paper.

2. AIM and hypotheses

The present study aims to investigate citizens' perceptions of flood risk through a SEM model building.

Information useful for describing citizens' perceptions of flood risk was collected through an online survey. The choice of using web to facilitate data collection and process management is now well known [29]. In the online survey design, risk perception is considered as the combination of the probability of occurrence (likelihood) and perceived damage (severity). Perceived risk exposure measures the expectation of being exposed to a flood, as probability, and severity, i.e., the expected damage if an event occurs [1]. Perceived risk was related to different variables defined following the theoretical model building (discussed in more detail in Section 3.2).

The theoretical model considered several lines of inquiry on risk perception investigated mainly in the works of Renn and Rohrmann [9], Renn [30] and Lechowska [31]. The choice of using Renn and Rohrmann [9] and Renn [30] from the field of psychology as a literature reference stems from the idea of exploring key findings from the social sciences that appear relevant to a deeper understanding of the role of risk perception in general, beyond flood risk, the specific subject of the present study.

These studies show that the mental models and other psychological mechanisms that people use to formulate perception (e.g., cognitive heuristics, trust in institutions or information from other subjects) are internalized through social and cultural learning and constantly moderated by media reports, peer influences, and other amplification and communication processes [9]. On the other hand, factors such as personal experience and risk assessment are essential for analyzing, helping, and improving communication [32]. All of these described elements are confirmed and implemented in the study of Leckowska [31], which describes in detail the elements that contribute to the perception of flood risk, analyzing the work carried out in recent decades. The theoretical model relates flood risk perception to two declinations of knowledge as defined by Lindell and Perry [33] and to demographic, socioeconomic, and physical-geographic variables.

Based on the knowledge gathered, the theoretical model proposed in this paper is constructed formulating the following hypotheses:

- Hypothesis #1: Knowledge of the causes of a phenomenon increases the probability of perceived risk. According to some authors [34,35], people who have little knowledge of the causes of floods have a lower perception of risk than those who know the nature of the phenomenon. This is usually the case in areas rarely involved in flood events [11,36], as in the Bari case study analysed in this paper.
- Hypothesis #2: The greater the perceived risk, the more likely citizens are aimed to take action to increase their knowledge measure. The concept of measure knowledge is mainly related to whether or not people take mitigation actions or adopt precautionary behaviours. In this relationship, discordant results are found in the literature. Indeed, while some cases recognize that increased knowledge correlates, albeit weakly, positively with precautionary behaviours [17,37], other findings suggest that knowledge is not always a useful predictor of mitigation behaviours, finding a negative or even absent relationship [34,38,39].
- Hypothesis #3: Demographic (gender, sex, residence), socioeconomic (education, income, family members, presence of young, elderly, and disabled in the household, prior experience, homeowners, communication), and physical-geographic (proximity to source of risk, type of house, floor where one lives) factors influence risk perception and knowledge of causes and measures [40–44].

Although the literature shows that several possible connections between the variables that can describe risk perception could be considered. At this stage of the work, the main purpose is mainly to test a model, still little used in the field of flood management (see Section 1), that can validate hypotheses with a low margin of error. In addition, it is also able to provide, on a preliminary basis, an overview of citizens' perception in the city of Bari, which is highly compromised by flood risk and which no one has ever investigated before. Then, a structural equation model was created to test the correctness of the hypothetical paths and discover new paths of flood risk perception, flood risk knowledge, socio-demographic and geographic factors in the specific case study. SEM is currently considered one of the most sophisticated methods for evaluating causal relationships between multiple dependent variables based on cross-sectional data, due to the incorporation of latent and observed variables and the inclusion of measurement errors [20].

3. Methods

3.1. Study area

Bari is a coastal city located on the Adriatic coast of south-eastern Italy, with 316,140 inhabitants and a territory divided into five districts (Fig. 1). This city is the capital of Puglia region and hosts a high number of administrative, economic and social structures, which make it a crucial hub also for surrounding regions. The municipality area lies on a limestone substrate which high permeability, which favoured the development of episodic karst streams called lame. The peculiar structure of these systems is likely to allow water runoff as a response to intense rainfall events. Geomorphological characteristics related to flood susceptibility of lame have been investigated in several studies (e.g. Refs. [45,46]).

Bari is crossed by several *lame*, whose path has been progressively interested from urbanization which in some cases lead to their disappearance or modification, reducing their cross sections and their hydraulic capacity. Moving from in NW-SE direction (Fig. 1), can be mentioned *lama Balice* (home to a Regional Natural Park), *lama Lamasinata*, *lama Picone*, *lama Valenzano*, *lama San Giorgio* and *lama Giotta*. The interconnection between the natural stream network and the city of Bari can also be recognised by the toponomy of the *Picone* neighbourhood (located in District 2, Fig. 1). This area was crossed by the homonymous *lama* until the 20th century when, after some destructive floods, was definitely deviated into the *Lamasinata lama* [47].

The evidence of the occurrence of floods in the area of Bari due to *lame* regime has been documented since the 16th century [48]. Destructive events happened in 1905, 1915 and 1926, whose memory is still traceable from some stone tables placed in affected streets [49]. Moving to recent years, a catastrophic event happened on October 22–23, 2005, whose dynamics and consequences were analysed in several studies [47,49]. Although there is historical evidence of past events, development in the city has grown without respecting the function of the *lame* [49]. They often host crops, housing, and infrastructure, leading the land to be more exposed to the impact of flooding, as documented by numerous accounts of damage following heavy rainfall events.

3.2. Theoretical framework

This paper aims to model the relationship between flood risk and the community by analysing and structuring risk perception through a SEM model.

Fig. 1. Geographical allocation of districts and lame.

The construction of a SEM model was preceded by the construction of a theoretical model based on a literature review, which was followed by the construction of the hypotheses set forth in Section 2 and graphically represented by Fig. 2.

The model is composed by two kinds of variables, called observed variables and latent factors. Specifically, the observed variables are represented by items related to socio-demographic profile, residence characteristics, proximity to risk, direct experience, and risk communication.

The latent factors are represented by (i) perception of risk, (ii) knowledge of causes, and (iii) knowledge of measures. The following cause-effect relationships exist among the latent factors (Fig. 2). The literature shows that knowledge acquired in different ways (e.g., through communication, the interaction between people, and personal experience) unequivocally influences risk perception [36,50]. In this study, the relationships between risk perception and knowledge in relation to causes of flood (relationship R1, Fig. 2) and measures (relationship R2, Fig. 2) were analysed.

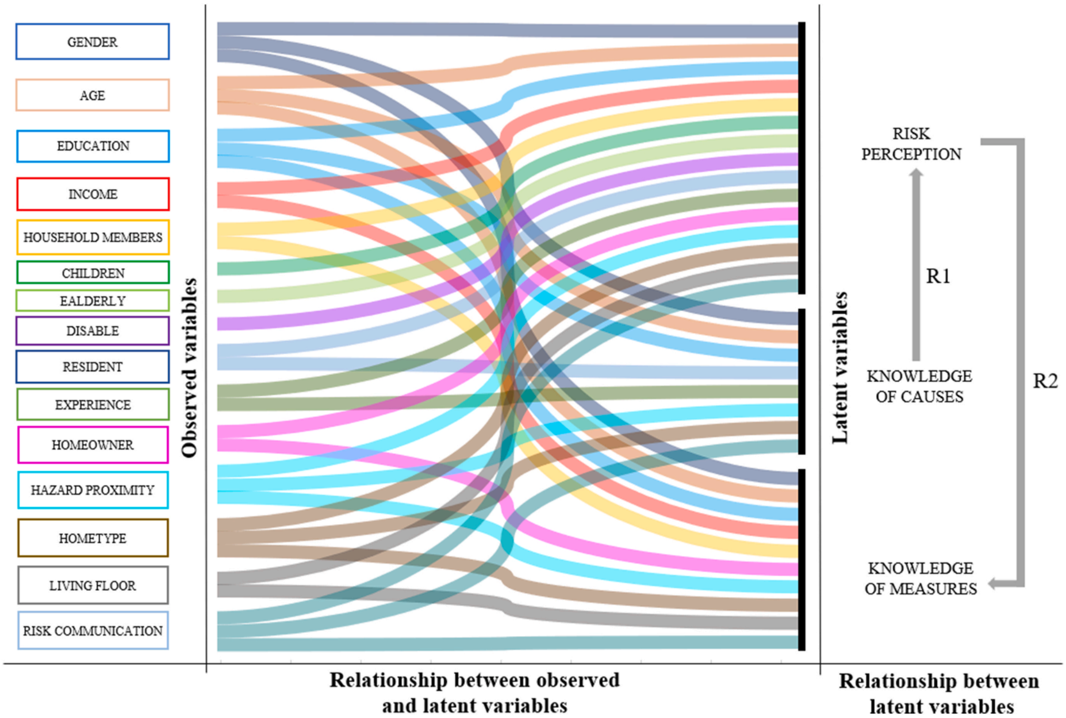

Fig. 2. Theoretical framework

The choice to relate flood risk perception to knowledge stems from the studies of Renn and Rohrmann [9] who developed a model of risk perception that integrates psychological, social and cultural factors. In this study knowledge is influenced by cultural and social factors, influences the heuristic processing of information that underlies risk judgments. In addition, the different declinations of knowledge to relate to perception were inspired by the work of Lindell and Perry [33]. They identified three types of hazard knowledge: knowledge of the causes of the hazard, knowledge of measures, and knowledge of exposure mechanisms to cope with the hazard. The first two were considered in this study.

The choice to relate perception to specific sociodemographic variables follows the literature examples shown below. Many studies include socio-economic and geographic factors to explain the relationship between flood risk perception and knowledge. Gender, age, educational attainment, residence, homeownership, and experience are variables that always characterise the user profile description in online survey that collect information on risk perception [32,40–42,44]. Therefore, in the model these observed variables are connected to the three latent factors.

Other studies related to risk perception collect information in relation to a family group, such as the number of people and the presence of children or elderly [6,22]. Resident or commuter status may act on risk perception and knowledge [6,32,42].

In addition, proximity to the source of risk may affect perception and knowledge of the phenomenon. Botzen et al. [34] find that individuals living near a major river have higher risk perception and that living near a river is marginally significantly related to mitigation demand and thus knowledge. Housing type and plan may also affect both perception and the ability to increase knowledge for protective purposes [51–53].

Finally, numerous evidence show that people assess risk from their personal experience and depending on communication. People with direct experience tend to show a higher level of flood risk perception [6,53], even though the literature suggests that this tends to disappear several years after the flood [54]. Therefore, the timing of the experience plays an important role. Communication networks in the form of media, personal interactions with other people, in other words, indirect experience, and a type of social ties, as well as social capital, are factors that modify the influence of knowledge on the level of risk perception [18].

3.3. *Methodology*

The research objectives were achieved through the structuring of the methodology depicted in Fig. 3.

In order to answer our research question, aimed at investigating and structuring the elements that influence citizens' risk perception and tested SEM application in order to support flood risk management and planning issues, a literature review was conducted within search engines such as Google Scholar, Web of Science/Knowledge and Scopus. It gathered studies analysing factors that influence citizens' risk perception and the different methods to structure it (problem statement). Subsequently, a theoretical model of SEM and the online survey framework have been designed (data structuring). The decision to use a online survey disseminated online was motivated by (i) the exploratory nature of the research, which was not constrained by the collection of a defined sample upstream, and (ii) to the ease with which a wider audience could be involved than the normal participation techniques provided in the literature (workshops, seminars, paper interviews, door-to-door, etc.), and the historical period in which the research was carried out. During the pandemic, the online mode was found to be effective and safe. Finally, the data were analysed through SEM.

3.3.1. *Online surveys*

The online questionnaire used in this study consists of 33 questions subdivided into five sections respectively, dealing with:

(i) demographic characterisation (age, gender, income, etc.);
(ii) investigation of citizens' risk perception;
(iii) investigation of the memory of past events;
(iv) investigation about the role of communication tools in emergencies;
(v) participants' potential behaviour in flood risk scenarios in an urban environment.

The online survey has been built as a combination of closed-ended questions with single, multiple, and/or Likert scale response options and open-ended questions. It was distributed from July to September 2020. Due to pandemic restrictions, it was disseminated online through social channels and snowball sampling. In this article the first two sessions of the online survey have been analysed. Specifically, the demographic variables have been used in the SEM model in order to define factors' influencing risk perception, according to the relationship shown in 3.2; citizens' risk perception has been defined as the combination of the probability of occurrence (likelihood) and its damages perceived (severity). Perceived risk exposure measures the expectation of being exposed to a flood

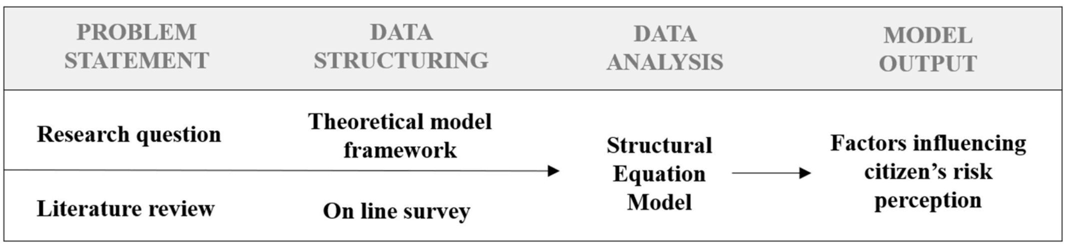

Fig. 3. Methodology flowchart.

as likelihood, and the severity, i.e., the expected damage if an event occurs [1] (questions n. 1 a,b, Table 1). This type of information could allow the decision-maker to investigate on different spatial scales the difference between perceived and real risk. Moreover, in order to understand the relationship between citizens' risk perception and knowledge, two questions have been added. The first, it aims to understand the degree of knowledge of defence measures in the three phases of a hazard (pre-event, during the event, and post-event), (question n. 2, Table 1). This type of information would help the decision-maker to evaluate the choices to be made in the different phases of the hazard cycle; the second question is aimed at understanding the degree of knowledge of the causes that generated the flood event (question n. 3, Table 1). This information could help the decision-maker to control inappropriate actions by citizens (e.g., abusive activities).

3.3.2. Sample

The study sample included 752 citizens with the characteristics shown in Table 2. The sample consisted of 50% of residents, whereas the remaining were non-residents. Among them, 58% of the respondents were male and 43% female. The age groups of respondents ranged from under 18 to 75, with an average age of respondents of 35. Most respondents indicated that they had a High school and Masters' degree education (32% and 34%, respectively). Regarding income, most respondents belong to the income range of 15.000–30.000. Most of the respondents live in a household of 4 people (46%). The presence of children, the elderly or people with disabilities is not reported in most respondents, while 59% of respondents live in a house they own. In relation to residence characteristics, 85% live in an apartment which is one floor above the first and do not live in hazard-prone areas (64%). In relation to the relationship with flood risk, 81% of respondents do not report past direct experience with a flood and have never witnessed a risk communication/awareness campaign (78%).

Hazard proximity was defined by the analyst by overlapping the map of neighborhoods with the hydraulic hazard map (PAI). All neighborhoods affected by hazard were classified flood-prone area.

3.3.3. Structural equation model

SEMs are multivariate regression models characterised by the fact that, in the same system of equations, each phenomenon involved in the network of causal relations covers the dual role of explanatory variable and response variable. Therefore, SEMs are very useful in the construction of a composite indicator [55].

SEM consists of two sub-models:

- the measurement model (Green boundary, Fig. 4) capable of defining latent variables, from observed variables;
- the structural model (yellow boundary, Fig. 4) that describes the causal relationships between the latent variables.

The model is represented by three basic equations: (i) the first equation (1) in which the three vectors of endogenous (η), exogenous (ξ), and error (ζ) variables are present. Γ represents the matrix of path coefficients between the endogenous and exogenous latent variables; B represents the matrix of path coefficients between the endogenous latent variables [56].

$$\eta = B\,\eta + \Gamma\,\xi + \zeta \tag{1}$$

The second equation (2) in which there are the three vectors of observed endogenous variables (Y), latent endogenous variables (η), and errors (ε). (Λy) represents the coef. matrix of the measurement model for the observed endogenous variables [56].

Table 1
Item of the questionnaire.

Latent variables	Questions	Items
Likelihood perception (RP)	1a. How likely do you think it will be that serious flooding will occur in	your district your city your neighbourhood
Severity perception (RP)	1b. Indicate the degree of damage you would expect due to a flood	in your district in your city in your neighbourhood
Knowledge of measures (KM)	**2.** Indicate your level of knowledge about:	mitigation measures protective measures post-event measures
Knowledge of flood causes (KC)	**3.** Indicate, according to your knowledge, the extent to which the following activities contribute to increased flood risk	the lack of hydraulic defence measures building growth in constrained areas improper sizing of the sewer system climate changes land morphology abusive activities waterproofing of natural areas lack of maintenance of sewerage lack of activities' social prevention

Table 2
Sample description.

Categories	Description	Percentage	Model's Variables code
Gender (GND)	Male;	57.66%	0
	Female	42.48%	1
Age (AGE)	<18	0.00%	1
	19-30;	50.07%	2
	31–45	36.88%	3
	46–60	11.98%	4
	61–75	1.20%	5
Education (EDU)	Elementary license	0.00%	1
	Middle school	1.07%	2
	High school	31.82%	3
	Bachelor's degree	18.11%	4
	Master's degree	34.49%	5
	PhD	14.65%	6
Income (per year_euro) (INC)	<7.500	11.85%	1
	7.500–10.000	7.59%	2
	10.000–15.000	16.51%	3
	15.000–30.000	31.96%	4
	30.000–50.000	20.11%	5
	50.000–70.000	6.66%	6
	>70.000	5.33%	7
Household members (HM)	1	5.33%	1
	2	15.05%	2
	3	28.36%	3
	4	45.81%	4
	5	4.79%	5
	≥6	0.80%	6
Presence of children (CHI)	Yes	21.97%	1
	No	78.16%	0
Presence of elderly (EAL)	Yes	23.44%	1
	No	76.70%	0
Presence of disable (DIS)	Yes	14.38%	1
	No	85.89%	0
Resident (RES)	Yes	49.67%	1
	No	50.47%	0
Experience (EXP)	Yes	19.44%	1
	No	80.56%	0
Homeowner (HO)	Yes	59.25%	1
	No	40.75%	0
Hazard proximity (neighbourhood) (HP)	flood-prone area Yes	35.69%	1
	flood-prone area No	64.31%	0
Home type (HT)	Apartment building	84.69%	1
	Isolated house	15.31%	0
Living floor (LF)	Ground floor	38.09%	1
	Beyond the first floor	61.78%	0
Risk communication (RC)	Yes	22.44%	1
	No	77.70%	0

$$Y = \Lambda y \, \eta + \varepsilon \tag{2}$$

The third equation (3) in which there are the three vectors of observed exogenous variables (X), latent exogenous variables (ξ), and errors (δ). (Λx) represents the coef. matrix of the measurement model for the observed exogenous variables [56].

$$X = \Lambda x \, \xi + \delta \tag{3}$$

Among the various existing structural equation models, those based on covariance were used for the present study have the purpose of obtaining estimates of the free parameters of the model while preserving the information contained in the observed variance/covariance matrix. They can be regarded as a generalisation of Confirmatory Factor Analysis dating back to Thurstone [57]. They rely on maximum likelihood (ML) to estimate the parameters of a model that involves causal links between latent variables in addition to measurement links.

Specifically, an Exploratory Factor Analysis (EFA) was adopted to reduce the number of items. To identify the factorial structure of the scale, EFA postulates were tested: the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. The KMO and Bartlett test from which a value of 0.9 emerged, considered valid to proceed with the analysis. Exploratory factor analysis used maximum likelihood extraction and varimax rotation methods to estimate factor loadings, coded as shown in Table 6. Through AFE, it has been possible to

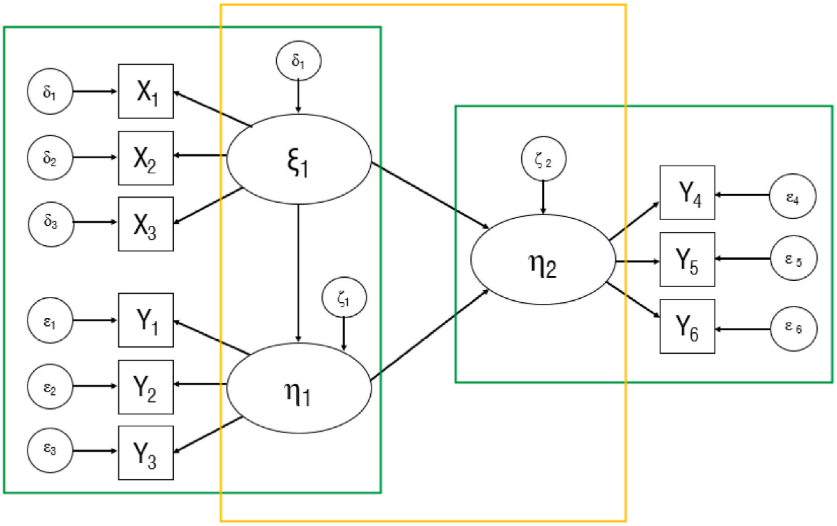

Fig. 4. Theoretical framework of SEM. Inspired by Anderson et al., 1988.

identify the most suitable items to measure the different latent factors, going from the initial 18 items (Table 4) to 9. Saturations with a value less than 0.4 are considered insignificant and therefore were excluded from the modelling. The remaining values were reordered in descending order as shown in Table 3.

The AFE results were analysed with AMOS 26 to run the SEM model and test hypothetical relationships between constructs.

4. Results

SEM structure is shown in Fig. 5. Variables bounded in ellipses are known as latent variables. The circumscribed variables in the rectangles represent the observed variables. The relationships between all variables are represented by the arrows.

The SEM is shown in Fig. 5.

The SEM model applies a theoretical framework defined after a literature review. It tests its validity under real-world conditions. The results of SEM are in line with the model hypothesised from the relationships found in the literature. Several indices of fit are examined to assess the fit of the path model: Chi-square (χ^2)/Degree of freedom (df). The root mean square error of approximation (RMSEA). The goodness of fit index (GFI). and the adjusted goodness of fit index (AGFI). The validity of the model is confirmed by reading the values in Table 4.

The SEM model confirms the relationships between the latent variables through acceptable R^2 values (Table 5). The SEM model also confirms the relationships between the observed and latent variables through statistically significant p-values (highlighted in bold in Table 6).

Table 7 shows the regression weights for predicting the latent variables from the observed variables.

The data are represented by the Pareto diagram (Figs. 6–8).

Looking at the values that emerged from the model (Table 5), it is possible to see an acceptable value of R^2 except for the latent factor 'Knowledge of Causes'. It is not surprising due as mentioned in the methodological section, latent variables are highly dependent on the study context. In fact, flood risk perception usually decreases 7 years after the flood [58] and this happens especially in places where events are not recurrent. The SEM model also confirms the relationships between the observed and latent variables through statistically significant p-values (highlighted in bold in Table 6).

As shown Fig. 6, the variable 'experience' has the greatest impact on the citizens' risk perception. This results confirm what has been widely stated in the literature [6,51,52,59]. The incidence of the variable experience is given by only a small portion of the sam-

Table 3
Value from Factorial Analysis (% cumulative variance explained: 69.174).

Item	Risk perception	Knowledge of causes	Knowledge of measures
1	0.939		
2	0.610		
3	0.572		
4		0.931	
5		0.718	
6		0.613	
7			0.999
8			0.666
9			0.568

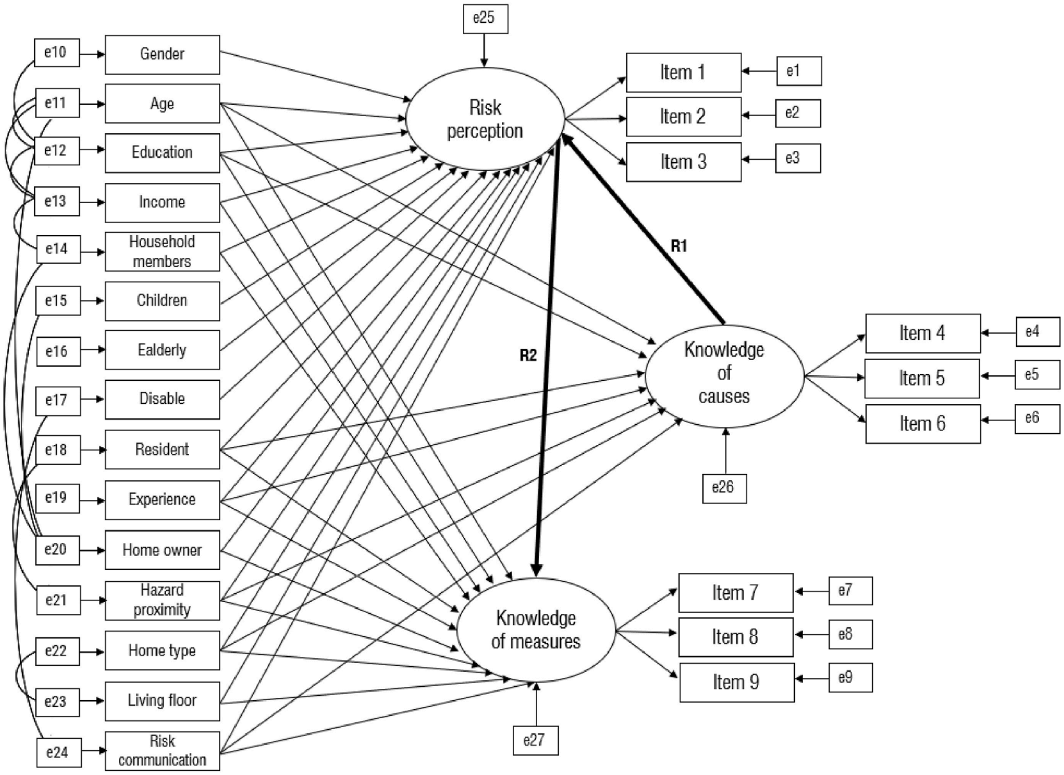

Fig. 5. SEM model build on AMOS 26.

Table 4
Model fit.

Model results	Optimal values
Sample size = 752	
df = 216	
Chi-square = 2298.121	
GFI = 0.899	>0.95
AGFI = 0.855	>0.90
RMSEA = 0.074	0.08 ÷ 0.05

Table 5
Squared multiple correlations.

Risk perception	0.9
Knowledge of measures	0.5
Knowledge of causes	0.3

ple involved. This can be explained by the fact that the last major event was 17 years ago, and the sample surveyed had an average age of respondents between 19 and 30. Moreover, without an adoption of communication strategies, flood risk perception usually decreases 7 years after the flood [58] and this happens especially in places where events are not recurrent.

Referring to the positive correlation between knowledge of causes and observed variables (Fig. 7), more than 80% of the population that claims to know about the causes of a phenomenon are residents, have acquired information through communication campaigns, and have an education level above a high school diploma. More educated people may have a better knowledge of floods [60] a clearer understanding of related terms and facts [34] and tend to expect less government assistance and approve flood protection payments at the property level [61].

Proximity to the source of risk involves just under 10% of the population. Considering that most residents do not live in areas close to the risk, the result is consistent. In any case, it is not a result to be underestimated, given the diverse nature of flooding, see Refs. [27,62]. Referring to the positive correlation between the knowledge of the measures the observed variables (Fig. 8), it is possible to see that those who are older than 45 years, residents, those who live in an isolated house and closer to the risk, are aware of the measures.

Table 6
Statistical significance in bold (*p value ≤ 0.05; **p value ≤ 0.1; ***p value ≤ 0.01).

			Estimate	P
KC	<---	GND	0.659	**0.000**
KC	<---	AGE	0.543	**0.000**
KC	<---	EDU	0.68	**0.000**
KC	<---	RES	0.764	**0.000**
KC	<---	EXP	0.604	**0.000**
KC	<---	RC	0.755	**0.000**
KC	<---	HP	0.074	0.483
KC	<---	HT	0.344	**0.018***
RP	<---	GND	0.057	**0.041***
RP	<---	AGE	−0.008	0.799
RP	<---	EDU	0.064	**0.027***
RP	<---	INC	−0.007	0.437
RP	<---	HM	−0.015	**0.067*****
RP	<---	CHI	0.069	**0.027***
RP	<---	EAL	−0.006	0.838
RP	<---	DIS	−0.067	**0.086****
RP	<---	RES	0.018	0.509
RP	<---	EXP	3.57	0.000
RP	<---	RC	0.055	0.201
RP	<---	LF	0.098	**0.075****
RP	<---	HO	−0.009	0.755
RP	<---	HP	0.018	0.515
RP	<---	HT	0.082	**0.076*****
RP	<---	KC	0.023	**0.026***
KM	<---	GND	0.28	0.000
KM	<---	AGE	0.955	0.000
KM	<---	EDU	−0.236	**0.008***
KM	<---	INC	−0.027	0.309
KM	<---	HM	0.353	0.000
KM	<---	RES	0.73	**0.000**
KM	<---	EXP	−6.22	**0.000**
KM	<---	RC	0.267	**0.038***
KM	<---	LF	0.109	0.523
KM	<---	HO	0.177	**0.039***
KM	<---	HP	0.388	**0.000**
KM	<---	HT	0.52	**0.000**
KM	<---	RP	1.753	**0.000**

Table 7
Regression weights for predicting the unobserved variables from the observed variable.

Observed variables	Latent variables		
	Knowledge of Causes	Risk Perception	Knowledge of Measures
HT	0.05	0.01	0.11
RC	0.11	0.01	0.06
HP	0.01	−0.01	0.08
EXP	−0.05	1.75	−0.65
RES	0.12	−0.03	0.14
EDU	0.10	0.04	−0.04
AGE	0.08	−0.05	0.18
GND	0.10	0.01	0.06
LF	−0.01	0.04	0.04
HO	0.00	−0.01	0.03
DIS	0.00	−0.03	−0.01
EAL	0.00	0.00	0.00
CHI	0.00	0.03	0.01
HM	0.00	−0.02	0.07
INC	0.00	0.00	−0.01

5. Discussion

This work represents one of the first attempts to assess citizens' flood risk perception and knowledge in vulnerable areas which have episodic stream called "lame"through the use of SEM. Lame are framed within the so-called 'episodic streams', which are characterised by the presence of water only after very intense rainfall events, with a temporality rate that is greater than one event in five

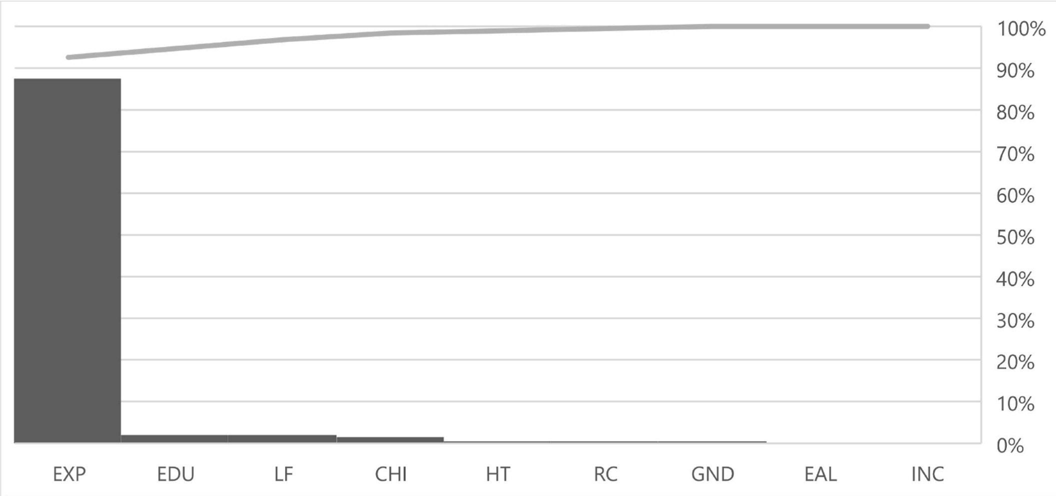

Fig. 6. The impact of the observed variables on Risk perception.

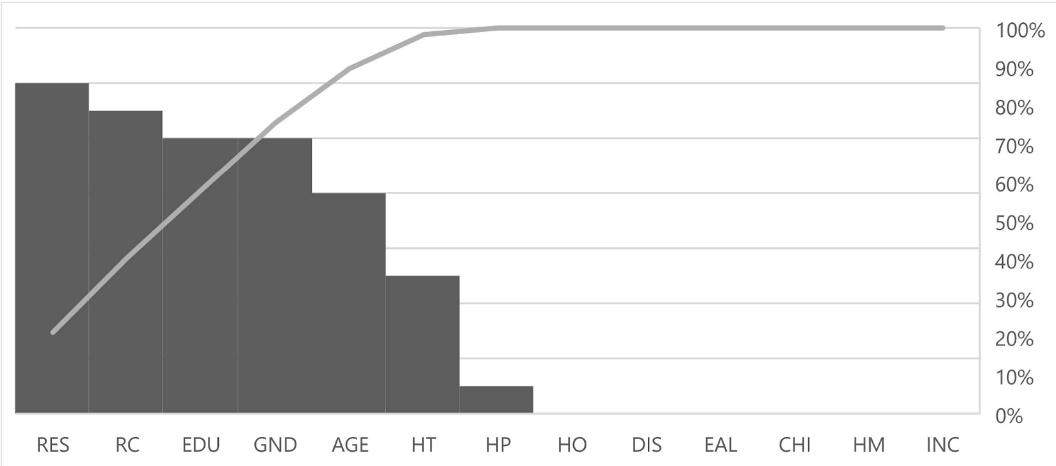

Fig. 7. The impact of the observed variables on knowledge of causes.

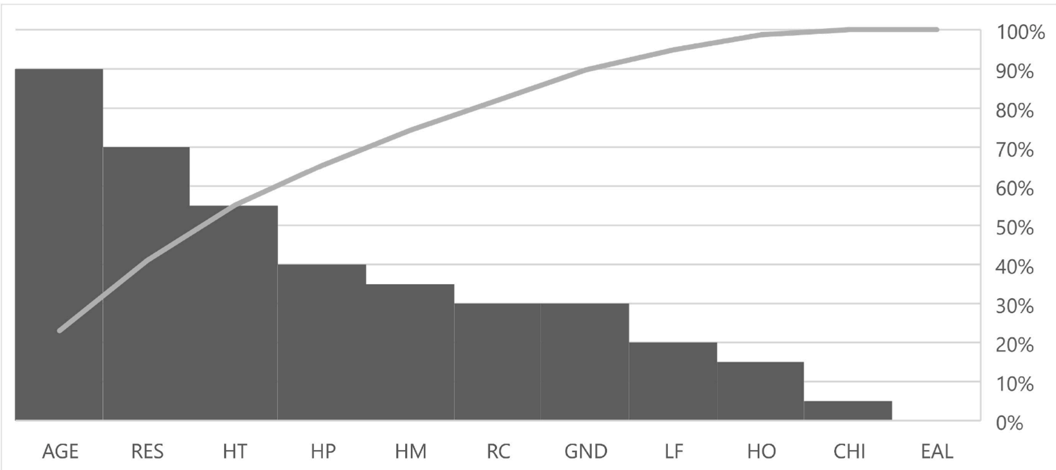

Fig. 8. The impact of the observed variables on knowledge of measures.

years. Consequently, these streams are often subject to urbanization, which is a barrier to the natural flow of water when rainfall events occur. In addition, these streams are often characterised by significant catchments, also exceeding 100 km^2, thus potentially giving rise to major floods. As such, one of the novelties of our approach consists in applying the proposed model to areas crossed by episodic streams, whose phenomenology is very different from those currently investigated in the literature and to which it would be important to draw attention.

Certainly, the exploratory nature of this study, inevitably led to a simplification of the components describing a flood phenomenon. Although the literature shows that there are several possible connections between the variables considered, at this stage of the work, the construction of the model was based on the analysis of the literature described in Section 3, with the main purpose of testing a model that is still little used in the field of flood management. In addition, it allowed preliminarily an overview of citizens' perceptions in the city of Bari, leading to several useful insights for emergency management and implications for spatial planning activities.

The results obtained confirm all the hypotheses described in Section 2. In fact, this work shows a positive correlation between knowledge of the causes and the increase in perceived risk (hypothesis 1). The higher the perceived risk, the more likely it is that citizens will take action to increase their knowledge of the measures (hypothesis 2). These results align with some known literature studies [17,37]. It must be mentioned, however, that this relationship is strongly debated in the scientific field. Indeed, the relationship varies depending on the context, to the extent that in some cases it reveals a negative correlation or even no correlation at all [34,38,39].

Further, it was found that several demographical factors, more than others, influence the perceived risk (hypothesis 3). Even though the study is located in a context characterised by 'lame', the results appear to be in line with studies set in permanent watercourse contexts.

The proposed findings lead to further reflections on the role of direct experience, which, with respect to other citizens' characteristics, appears to be context-independent. In fact, the model also highlights that the age range of the population reporting to have a flood experience is 46–60 years old. From a risk management perspective, this can be important information for planning timely communication strategies.

This result also brought out a limitation related to the approach used through an online survey. This approach was found to be not very inclusive, involving a low sample of the population with age over 46. In addition, it was found that residents and people with an education level above a high school report knowledge of the causes of the phenomenon in the city.

The SEM model also suggests that the category of citizens that should be considered to increase knowledge of causes are commuters and people with an education level below high school. This result is quite predictable considering that lame, unlike perennial streams, are not visible and are often occupied by urbanization developments. Therefore, people who do not live in the city or know it little, do not recognize a potential danger in certain areas.

In terms of measure knowledge, the 46–60 age group and, to a lesser extent, the 30–45 age group, residents, people living in an isolated house, and people living in at-risk areas are found to know the measures. The SEM model also suggests that the category of citizens who should be considered to increase knowledge of the measures are citizens under the age of 30, commuters, people who live in buildings at ground level, and people who do not live near the hazard. Based on these findings, some non-structural measures could be undertaken to improve flood risk management. For example, initiate participatory processes to develop a shared vision of the phenomenon that reflects the concerns of emerging categories of citizens to provide ideas for collective mitigation actions. Plan awareness campaigns to reach emerging categories through social media (for youth); school seminars (for youth up to age 20); institutional websites (for other categories of citizens) also potential initiatives to be carried out (see Refs. [63–66]).

The SEM approach used in this work allowed testing the relationship between the three latent factors investigated in this work based on the existing literature (see Hypothesis 1 in Section 2). However, the relationships between these variables can have a more complex interconnection. For instance, the proposed results in Section 4, shows that knowledge of flood causes (KC) have a significant impact on risk perception (RP) while risk perception has a significant impact on knowledge of measure (FM) as illustrated in Table 5. However, it could be possible to argue these three factors might have many more joint interconnections which evolves over time. For instance, higher risk perceptions can lead to more knowledge of measures (as predicted by the proposed SEM model) as well as more knowledge of measures can lead to lower risk perceptions because the person knows that they can protect themselves once this knowledge is acquired.

Finally, the dynamic change in risk perception and flood knowledge is likely to affect citizens' response and their protective actions over time. These relationships were not investigated in this work as the questionnaire was administered only once to the participants. As such, it was not possible to assess how the change in risk perception and knowledge affected citizens' responses. This represents a limitation of this work, and this dynamic structure requires further investigations in future studies. On the other hand, given the sample size of this study ($n = 752$), this work provides a valuable dataset to test the hypothesis highlighted in Section 2 and provide a picture of the existing status quo for the selected case study.

6. Conclusions

This paper provides an assessment of citizens' perception of flood risk through the construction of a Structural Equation Model to identify useful elements to support flood management in the Bari area, which is burdened with structural problems of a geohydrological nature.

The purpose of this work is not only to assess citizens' flood riskperception , which poses complex decision-making problems for planning and management of future organisations and territories, but also to test a model that has not yet been explored in the field of flood management, but which we believe has important potential.

Furthermore, it draws attention to an aspect little investigated in the literature. In fact, research on flood risk perception focuses on areas traversed by episodic watercourses, often subject to an urbanization which obstruct the natural flow of water when rainfall occurs, with considerable effects on the territory.

The methodology proposes the combination of an online survey to collect data on citizens' flood risk perception and a Structural Equation Model from structuring them.

This work adds to the many risk perception structuring studies aimed at supporting flood risk management processes, but through an under-explored approach.

Structuring citizens' flood risk perception through SEM could add value to the current scientific and technical debate. Indeed, in the field of flood management, among others, there are difficulties related to:

(i) the collection of information related to the social sphere [29];
(ii) structuring components related to the social sphere [27,31].

Which are addressed in the present study as follows:

(i) referring to the techniques of collecting and managing information through an online semi-structured interview, which has the advantage for the analyst to create a database to be checked and analysed in a short time, information to be spatially located, and data to be used for more accurate analysis. Elements that would improve the flood risk management process by planning more precise strategies focused on specific categories of citizens based on their demographics and location in an urban area at risk. The use of this approach certainly has limitations: one is intrinsic, the others are related to the limiting conditions linked to the period of health emergency in which the work was carried out. In fact, the type of questions set on a Likert scale provides results in an aggregate form of citizens' perceptions, neglecting possible facets. Known for example from open-ended questions. Again, however, problems would arise related to the interpretation and analysis of textual data. In addition, it would have been interesting to include the perception and knowledge of citizens who do not use the web platform and to disseminate the survey in a targeted manner in different geographical areas.
(ii) In relation to structuring the components related to the social sphere. in this study, risk perception was analysed as a set of different components. In the literature, these components are addressed according to many approaches. Such as Rationalist and constructivist paradigms (see Ref. [67]).

On the other hand, although created based on a search of the most used elements in the literature. it provides a basis for a broader model that could be implemented with additional variables. This element represents the added value related to replicability and the ability to implement the model.

In addition, the role of social science and public participation in building the model remains crucial. It could certainly be improved by incorporating social science input, the adoption of this methodology has allowed us to understand how distant the memory of citizens is and, consequently, how remote the perception of flood risk is. Despite this limitation, it was possible to deduce that there are no more places than others, which may represent a potential danger for citizens because the proximity to the source of risk was not found to be a variable that produces implications on perception. Also, knowledge of the causes of the phenomenon is possessed more by residents and by those who either have witnessed information campaigns or have a higher level of education. Furthermore, knowledge of the causes of the phenomenon implies an increase in the perception of risk; residents also possess knowledge of the measures to be taken along with those who are over 45 years old (and who have probably experienced the event) and those who live in isolated houses. This is probably because they have been called upon to act on their own.

The assessment of citizens' perception exploiting SEMs could help in building a deeper knowledge deriving from their experiences, composite background, expectations, previous direct/indirect experiences of flooding, frequency and severity of events - which influence the behavioural choices to adopt precautionary measures in hazard situations. It could show citizens' weaknesses and vulnerabilities that would not emerge with traditional approach to define structural measures [68].

It is crucial that urban and emergency plans should work in synchronicity and represent the result of multidisciplinary and multi-actor processes aimed at assessing the available resources, the perception and attitude of the population involved and the needs to be met during the emergency phase [69].

This work represents just the beginning of a research path aimed at building agent-based models from which it appears that improving communication and incentivising participation to increase knowledge and help support flood risk management in choosing more timely and effective strategies.

Credit author statement

Stefania Santoro: Conceptualisation. Writing: original draft. Methodology. Data collection and curation. Formal analysis. Review & Editing; Ruggiero Lovreglio: Conceptualisation and Methodology. Writing: Review & Editing; Vincenzo Totaro: Conceptualisation. Writing: original draft. Review & Editing; Domenico Camarda: Conceptualisation. Writing: Review & Editing; Vito Iacobellis: Conceptualisation. Writing: Review & Editing; Umberto Fratino: Conceptualisation. Writing: Review & Editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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